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# Arizona Mineral Resource

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## What We Can Expect From Renewable Energy

by Dr. Madan M. Singh, Director

Renewable energy is energy from sources that are replenished by natural sources, such as heat or light from the sun, wind, tides, geothermal, and vegetation (including algae). It has become a matter of national policy to develop renewable energy in the country. The American Recovery and Reinvestment Act of 2009 includes \$4.6 billion for renewable energy projects. The reasons for this are twofold:

“The Arizona Commerce Commission has mandated that the Arizona utilities produce 15% of their total electric power consumption from renewable sources by 2025 (16 years from now).”

- 1) To reduce the amount of carbon released into the atmosphere to decrease global warming. There is considerable debate as to the causes of the climate change that is occurring, and the impact of the human contribution; time will help to clarify that situation. At the present time there is a concerted effort to minimize the carbon footprint and substantial resources are being devoted towards its diminution.
- 2) The nation has become “addicted” to the use of oil. Over 58% of our petroleum products are imported; much of it is from countries that are not friendly to the United States. It is a significant portion of the national debt.

Therefore, it behooves the nation to develop its own sources of energy. What can be the contributions from various sources?

According to the Energy Information Administration (EIA), in 2007 the amount of total energy consumed by source is shown at right:

Coal	32.7%
Natural Gas	27.6%
Crude oil	15.1%
Natural Gas plus Liquids	3.4%
Nuclear	11.7%
Hydropower	3.4%
Geothermal	0.5%
Solar	0.1%
Wind	0.4%
Biomass	5.0%

### Solar and Wind

Most often when renewable energy is being considered, it refers to solar or wind. In 2008, the total amount of electricity generated was 4.1 billion megawatt-hours, of which 45.5 million megawatt-hours (1.1%) was from solar and wind. Recently President Obama stated that the amount of electric power from solar and wind would be doubled in three years. This would only give 2.2% of the electric power required. If this was doubled again in another three years and then again in still another three years, there would still be only 8.8% in nine years. This assumes that the total need for energy would not increase, in spite of an increasing population and a higher standard of living. Assuming that there would be other renewable energy sources also contributing, let us say that the total amount of electricity from these sources will be 15%. In fact, the Arizona Commerce Commission (ACC) has mandated that the Arizona utilities produce 15% of their total electric power consumption from renewable sources by 2025 (16 years from now).

## Renewable Energy cont.

In Arizona the emphasis is on solar because of the number of sunny days, over 300, in the Valley and the surrounding desert. Arizona does not offer many suitable sites for wind power generation, although a few wind farms are being considered; the Dry Lake Wind Project is being developed by Iberdrola Renewables and the Navajo Nation is contemplating a wind power generation station.

The Arizona State Office of the U.S. Bureau of Land Management (BLM) has nearly 40 applications for solar power generation to date. Abengoa Solar's Solana Power project near Gila Bend is planned to generate 280 megawatts of power and occupy 1,900 acres. If the other plants require a similar amount of space this implies stripping nearly 75,000 to 80,000 acres of desert. The amount of water used in most solar plants could be matter of concern in desert areas. The Solana plant will require only a 20-mile, 230-kilovolt transmission line to connect into the existing Arizona Power Service (APS) grid. Most of the new plants will probably be further



*Six dish Stirling Systems developed by Schlaich Bergermann und Partner of Stuttgart, Germany, in operation at the Plataforma Solar de Almeria in Spain.*

away from the power users (cities); this will require long transmission lines. Albiasa Corporation is planning a 200 megawatt solar plant near Kingman. Science Foundation Arizona has recently organized the Solar Technology Institute and committed \$4 million to that program.

In July 2008, the Texas Public Utility Commission approved the construction of nearly \$5 billion worth of transmission lines to convey electricity from new wind farms in West Texas and the Panhandle to metropolitan areas like Austin, Dallas, and Houston. When construction is complete, utility bills for residential customers will increase by about \$4.00 per month. Idaho Power is planning a 298-mile, 500 kilovolt power transmission line

from Boardman to Hemingway, Idaho. The company assumed it would be easier to route it over farmland than to challenge environmental groups if the route involved wildlife habitat. However, Eastern Oregon farmers declare the proposed route would disrupt irrigation patterns and interfere with aerial spraying that controls insects and weeds. Objections to transmission lines may be expected elsewhere in the country. This is why Senators Jeff Bingaman and Harry Reid have proposed separate draft legislation that would give the Federal Energy Regulatory Commission (FERC) authority to approve transmission-line projects from renewable energy generators to user locations, thereby speeding their development.

Nineteen (19) companies have submitted applications to build 14 solar and five (5) wind energy facilities on a parcel of 500,000 acres in California's Mojave Desert, referred to as the former Catellus lands. Concerns have been raised about the aesthetics of the region and its tortoise population by environmentalists. Senator Dianne Feinstein said the development would violate the spirit of what conservationists had intended when they donated much of the land to the public. Similarly protests may be anticipated in Arizona and other sites.

## Renewable energy cont.

Energy from solar is intermittent and must be supplemented with a base load, unless it is stored in some manner. This may imply that traditional electrical generating systems (oil, gas, coal, nuclear) may have to be additionally installed although they may not be required to run at full capacity at all times. If that is the case, additional costs may be incurred for the conventional systems that will be borne by the consumer.

### Hydropower

Hydropower contributes approximately 6% of the nation's electricity, but there is now a strong movement to demolish large dams rather than build new ones. No large hydroelectric plants in the U.S. are planned at this time. Most of the hydropower in the United States is produced in three states – Washington, Oregon, and California.

Small scale hydro, under one megawatt, and microhydro, under 100 kilowatts, are still considered viable and recently a listing of 5,677 sites was produced for 49 states (Delaware is excluded because of its scarce resources), with the potential for generating 30,000 megawatts of electricity. Arizona has the capacity for 1.8 megawatts, according to this survey.

### Geothermal

As the name implies, geothermal, energy uses the heat of the earth.

This is generated by the decay of radioactive materials near the surface of the earth and close to water sources that bring the heat up to the surface. If the temperatures are above 300°F (~150°C), the resource is considered capable of generating electricity. If the temperatures are below 300°F (~150°C), these are normally not considered for electric power but

may be used for a number of other purposes. In Arizona three locations are known for geothermal water use – Childs on the Verde River, Castle Hot Springs in the Bradshaw Mountains, and Buckhorn Baths in Apache Junction. In addition there are two hot springs, Clifton and Gillard, both in the Clifton-Morenci area, with temperatures in the range of 158 – 180°F (70°C – 82°C); at depth these may exceed 284°F (140°C). Using geothermal energy for a hot house in Santa Cruz County is being considered.

### Biomass

Biomass energy refers to the use of energy stored in plants through photosynthesis and transferred to animals through food. This energy is then utilized to produce electricity or biofuels. If combustion is involved, carbon dioxide, CO<sub>2</sub>, is released into the atmosphere. Biomass is commonly found as wood products, dried vegetation, crop residues, and aquatic plants. It is often used as wood chips and has gained popularity in the developed countries in the last couple of decades. It has been used more in developing nations because of its ready access and low cost. Currently the burning of wood to produce heat directly or making charcoal may be contributing nearly 13% of the energy consumed on the planet. Some of this is not environmentally sound practice since it requires cutting down forests, as in the making of charcoal in Kenya. In that country nearly 82% of the population, including urban dwellers, burn charcoal. The annual production of charcoal in Kenya is 2.4 million tons. The deforestation of Finland, Scandinavia, England and Central Europe in the past may be attributed to the making of charcoal and tar. Denudation of forests generally results in irrevocable ground erosion and considerable water pollution – large scale ecological changes.



*Hoover Dam*



## Renewable energy cont.

The Federal government has established a goal of replacing 30 percent of today's transportation fuel with biofuels by 2030, and the Obama administration plans to support biofuel research with money to help test the new technologies in pilot plants and manufacturing facilities, and in the development of new products. The use of corn for making ethanol caused major dislocations in the world's food supply, especially in developing countries. Brazil produces ethanol from sugarcane which is more efficient.

Forest Energy Corp. has a plant near Show Low that uses 120,000 green tons of small-diameter wood from the White Mountains to produce 50,000 tons of pellets, enough to heat 25 million square feet of building space. Now they are in the process of discussing the possibility of a plant in Prescott for using the trimmings from the forest in the region. The firm is also negotiating with the Drake Cement plant to replace the coal for the drying of limestone with biomass.

Renegy Holdings, Inc. started commercial operation of its Snowflake biomass 24-megawatt plant in June 2008 to supply the Salt River project (SRP) and Arizona Power Service (APS) with electricity. SRP and APS signed 20-year Power Purchase Agreements (PPAs). SRP is getting 10 Mw of power for the first 15 years and 20 Mw during the next 5 years. APS will purchase 10 Mw of electricity for 15 years. Wood waste supplies the plant with 50% by weight (75% by BTUs) and the other 50% by weight (25% by BTUs) will come from the Catalyst Paper Corp.'s recycled paper sludge (which was previously being placed in a landfill). The plants are located adjacent to one another.

Energy from biomass is considered renewable because the plants used can be re-grown rapidly, whereas the energy in coal and oil was captured millions of years ago. Tree plantation for energy is a desirable goal, but only few cases of plantation-grown fuels to date are currently known. Biomass is at best a supplement to other forms of energy, since replacing all the energy requirements of the United States would imply foresting nearly one million square miles of land; which is one-third of the land occupied by the 48 contiguous states. Obviously that is an impractical task! It is also not clear that biomass energy is indeed cost competitive with conventional fuels – oil, coal, and natural gas.

## Ocean Energy

The relative motion of the earth, moon, and sun interacts with gravitational forces to create ocean tides.

These result in water level changes and tidal currents. The magnitude of the tide depends on its location on the earth's surface, the position of the moon and sun with respect to the earth, the effects of the earth's rotation, and the shape of the ocean coastline and floor. Since the motions of the earth and moon relative to the sun will continue indefinitely, tidal power is considered renewable. Several technologies convert the energy in tides to electricity, and new research is in progress. Cook Inlet in Alaska is considered to be a good location for generating tidal power. Two companies that had planned to install tidal power turbines in the Piscataqua River between Maine and New Hampshire have recently withdrawn their preliminary permits, partially due to ecological concerns.



*Large storm waves can create problems for wave energy projects.*

## Renewable energy cont.

Oceans are a large reservoir of heat from the sun; it warms up the surface layers. As long as there is a thermal gradient of nearly 36°F (20°C), it is possible to generate power. The oceans could serve as a renewable energy source, capable of producing as much as  $10^{13}$  watts of base load power. Some experimental work in this area was conducted by the United States off the coast of Hawaii. Japan has also explored this resource. The ocean energy sources are obviously not applicable to Arizona.

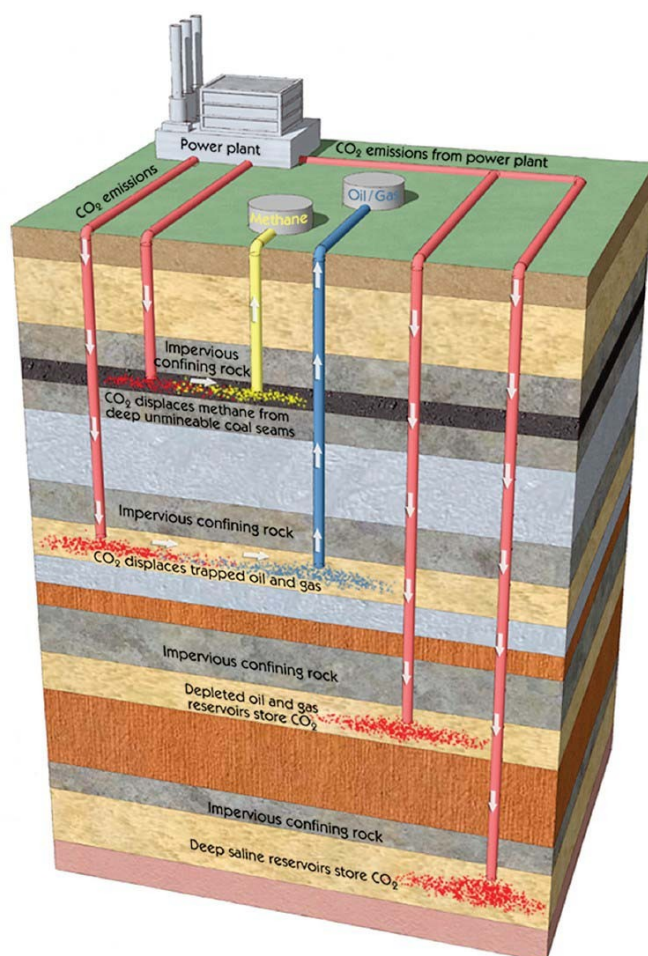
It is evident from the above discussion that the United States will not be able to wean itself from imported oil in the near future by relying solely on renewable sources. Other energy sources that are available in the United States need to be considered towards that objective.

## Coal

There are large deposits of coal in the country; enough to supply energy at the present rate of consumption for over 300 years. Currently about half the electric power is generated from coal. A concern with coal power plants is that that carbon dioxide (CO<sub>2</sub>) is emitted into the

atmosphere, which is one of the causes of global warming. Efforts are now underway to capture these emissions and pump them underground into porous rock formations.

### Carbon Sequestration



*Diagram courtesy of Ohio Department of Natural Resources, Division of Geological Survey.*

The Arizona Department of Environmental Quality and U.S. Environmental Protection Agency have recently (March 2009) issued permits to the West Coast Regional Carbon Sequestration Partnership (WESTCARB), to which APS belongs, to pump the CO<sub>2</sub> into the ground at its Cholla Power Plant, near Holbrook, AZ. The gas is to be pumped into a saline formation 3,500 feet deep. The gas is expected to remain contained there, and will not contaminate the drinking water in the area. The process is known as carbon capture and storage (CCS) or carbon sequestration. The U.S. has formed seven Regional Carbon Sequestration Partnerships, such as WESTCARB, throughout the country.

Coal-to-Liquid (CTL) fuels entails converting coal into liquid fuels that could be competitive with oil. In 1925 the Fischer-Tropsch process was perfected and Germany used this during World War II to fuel its tanks and vehicles. In the 1950s South Africa developed the SASOL process, and has used it since. During the last

## Renewable energy cont.

30 years the United States government, in cooperation with industry, has concentrated research in the area and improved processes, catalysts, and reactors. The Australian-American Energy Co. is proceeding with plans to build a \$7-billion CTL plant on the Crow Reservation in Montana, even though it expects to break even at \$75 to \$80 per barrel of oil. They claim that in the long-term the price of oil will rise in spite of the downturn at this time. It plans to produce 50,000 barrels per day of diesel and other fuels, and capture 95% of the CO<sub>2</sub> generated. Ambre Energy, another Australian company, is contemplating building a \$375-million plant in southeastern Montana to produce high-efficiency coal and synthetic crude oil.

Clearly the technology for commercialization of coal-to-liquids exists, although at this time China may well be ahead in this respect. The Shenhua plant in Inner Mongolia will start producing 20,000 barrels of oil a day using 3.9 million tons (3.5 million metric tons) of coal per year this year. China uses 7.2 million barrels per day of oil at the present time, so in 2010 the plant will start expansion to produce 286,000 barrels per day using 149 million tons (135 million metric tons) of coal per year. This is still only 4% of Chinese consumption at the present rate. In the U.S., Australia, and India CTL is being considered but being hindered by the controversy over CO<sub>2</sub> release, and water and energy usage.

With traditional coal power production, carbon emissions of China's electric power sector jumped by about a third in 2008 and surpassed the total emissions of the U.S. electric power industry for the first time. Chinese power plants produced about 3.1 billion tons of carbon dioxide (CO<sub>2</sub>) in 2008, up from about 2.3 billion tons in 2007. U.S. power plants produced about 2.8 billion tons of CO<sub>2</sub> in 2008, about the same as last year. If all planned power plants for China and U.S. are built, China's power-related emissions would exceed those of the U.S. by 40 percent. However, the United States spews more CO<sub>2</sub> per person than other nations. Electricity usage here produces about 9.5 tons of CO<sub>2</sub> per person, compared with 2.4 tons in China, 0.6 in India and 0.1 in Brazil.

## Nuclear Power

Nuclear power plants produce no air pollutants such as sulfur, mercury, greenhouse gases, or particulates. Dr. El-Baradei, Director General of the International Atomic Energy Agency and Nobel laureate, has stated (2005), "Nuclear power emits virtually no greenhouse gases. The complete nuclear power chain, from uranium mining to waste disposal, and including reactor and facility construction, emits only two to six grams of carbon per kilowatt-hour. This is about two orders of magnitude below coal, oil, and even natural gas." Along with fuel cells, this source of power would reduce the dependence of the U.S. on foreign oil.

There are 104 nuclear power reactors in operation in the United States at the present, with 120 waste storage locations in 39 states. Some of plants have been in operation for 40 years, e.g. Oyster Creek in New Jersey. Only one plant in the U.S., Three Mile Island, has had a serious radiation leak; even that resulted in no fatalities. The nuclear submarine program has been active for nearly six decades, since it was started by Admiral Rickover, and there have been no significant incidents of radiation leakage. In addition there are carriers and other ships that are traveling safely throughout the world. Thus nuclear power is among the safest in the world and is inexpensive to generate. According to the testimony by Anthony R Pietrangelo, Vice President of the Nuclear Energy Institute to the Subcommittee on Clean Air and Nuclear Safety, U.S. Senate Committee on Environment and Public Safety (July 2008), in 2007 the industry's capacity was 91.8% and the reactors produced 806 billion kilowatt-hours at an average production cost of 1.76 cents per kilowatt-hour –

## Renewable energy cont.

both new industry standards. Unfortunately, there is an exaggerated concern among some of the population about nuclear waste storage. In spite of the dispersed location of the wastes at this time, no problems have arisen. It appears that the government has adequate confidence in the safety of storage near power plants to stop further work on the Yucca Mountain deep-storage project without a named alternative site. It will probably take a few years to select another acceptable site, and several more years to develop the same.

At present the nuclear power plants are producing about 2,000 tons of waste a year. If the waste was re-processed and the Integrated Fast Reactor technology adopted, the amount of waste would be decreased considerably, and even more energy would be generated. Reprocessing is being done in France and the U.K. The 59 reactors in France produce 77% of the electricity in the country. In October 1976 President Ford issued a directive to suspend commercial reprocessing of plutonium with the objective of minimizing the risk of proliferation of nuclear weapons material, and in April 1977 President Carter confirmed this policy. With seven countries that are known to have nuclear arsenals and the technology to produce them, at least two others that have nuclear weapons and a number of other countries working towards gaining the knowledge, it may be time to review this policy.

At this time there are 436 power reactors in operation worldwide, and 44 more are under construction. In addition to the ones mentioned above, Japan has 53 operating and two (2) under construction, the Russian Federation 31 and 8, the Republic of Korea, 20 and 5, U.K. 19, Canada 18, Germany 17, India 17 and 6, Ukraine 15 and 2, China 11 and 11, Sweden 10 and the rest in a number of other countries. This wide range of experience should help build the confidence needed among the populace for building new plants. To date there are 29 applications entailing 34 reactors filed with the U.S. Nuclear Regulatory Commission for review and permitting.

According to the Energy Information Agency the total uranium reserves of U.S. are 890 million lbs of  $U_3O_8$ . It is estimated that the Arizona Strip has 375 million lbs of  $U_3O_8$ , equivalent to 13.3 billion barrels of oil (as much the oil recovered between 1977 and 2005 from Prudhoe Bay). All of this land is being considered to be withdrawn from mining. There were operating mines in the area in the 1980s with no known harmful effects; the mines have now been reclaimed. It is challenging to discern their existence at this time. The land withdrawal will increase our dependence on foreign oil, not reduce it.

## Conclusion

Although it has been suggested that the United States obtain all its energy from renewable sources within a decade, this would imply an infusion of massive amounts of resources by the government, even if it is feasible. With the present state of the economy and the need to stabilize the banking system, this does not seem like an attractive course. It is more realistic to expect that a major amount of energy be generated from renewable sources within the next 25 to 50 years. In the meantime more thought should be given to traditional energy sources, making them more environmentally acceptable. The emphasis should be on reduced dependence on foreign sources, which will result in economic and political benefits for the nation. The United States does have oil reserves, along with natural gas and oil shale. The vast amounts of coal and occurrence of deposits of uranium within the country should be given careful deliberation in the national energy mix.

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## Copper Gallery-Phase 1– Completed!

As soon as the Department moved into its new facility in the former Shrine Temple building in 1991, the vision of a “Copper Gallery” began to take form; an entire display area that told the story of copper in Arizona. Through the years the ideas, the desire, or the dedication were never in short supply; money to execute the dream has always been the roadblock. Now, with the help of many organizations and individuals, and years of planning and hard work, Phase I of the Copper Gallery, the panels and cases along the north wall, are in place. The eight panels depict the large copper mines in the state, with photographs and text describing the operations displayed alongside a case with ore specimens from the mine. The featured mines are: Bisbee, Ray, Morenci, Ajo, Tiger, Silver Bell, Bagdad, and the Superior-Globe-Miami area mines.

The Department wishes to extend our sincere thanks to the following companies and individuals who contributed to the construction of the panels:

**Arizona Prospectors Association**  
**Charlie and Kathy Connell**  
**Stuart and Linda Corliss**  
**Exhibit Services**  
**Friends of the Arizona Mining and Mineral Museum**  
**Maricopa Lapidary Society**  
**Mingus Gem and Mineral Club**  
**Phelps Dodge Foundation (now Freeport McMoRan Copper and Gold Foundation)**  
**Deanna Smith**  
**Wickenburg Gem and Mineral Club**

And now. . . we can move on to Phase 2 - interactive kiosks.



## Mining Foundation of the Southwest Funds Education Curator Position



*Pamela A. K. Wilkinson*

The Mining Foundation of the Southwest is funding an Education Curator position at the Arizona Department of Mines and Mineral Resources. Pamela A. K. Wilkinson has been selected for this position; she began work on March 30.

Pam came to the Department from the Arizona Geological Survey where she was employed as a geologist and worked on the geology of Southern Arizona basins. Pam received her B.S. in geology, and became a certified teacher, at the College of William and Mary, in Virginia. She received her M. S. degree in geology from Eastern Kentucky University. After completing her education Pam worked as an exploration geologist for Duval Corporation and U.S. Borax and Chemical Corporation. Her exploration experience is in borates, sulfur, potash and a variety of

other industrial minerals. More recently Pam has worked as a volunteer and scientist-in-residence for grades K-6. She taught, developed lesson plans, and led field trips on a variety of geology and mining related subjects.

Pam is a member of the American Institute of Professional Geologists, American Association of Petroleum Geologists, Geological Society of America, National Earth Science Teachers Association, National Association of Geoscience Teachers, Arizona Geological Society and the Tucson Gem and Mineral Society.

Dr. Madan M. Singh, Department Director, stated, "Pam's background in education, geology, and mining make her exceptionally suited for this job. Her enthusiasm for teaching and for mining should serve her well in this position."

The education curator is tasked with developing and implementing educational programs that cover the methods of modern mining, from exploration through development and production to reclamation. The purpose of the Mining Foundation of the Southwest, a non-profit organization, is to promote public understanding and education related to the mining industry. They have chosen to fund the position at the Arizona Department of Mines and Mineral Resources as the best place to position one person to reach out to a large segment of the population in Arizona.

"This position is an exciting opportunity to generate public understanding of how important mining is to our economy, our lifestyle, and our quality of life," Pam says.

### Resolution Copper Supports Outreach Position

Many thanks to Resolution Copper Mining for their \$1500 donation to the Mining Foundation of the Southwest to help fund the Education Curator position at the Department.

Resolution Copper goes to great lengths to support programs targeted at education. The company partners with environmental, government and other civic organizations with aid that includes in-kind donations, scholarships, and company internships.

## New Publications

The following new circulars are available as PDFs at our website. They are available in hard copy for a nominal charge.



**C-130 Federal Agencies Concerned with Mining and Mineral Resources in Arizona, 2009.** Contains addresses of Bureau of Land Management, Forest Service offices, and other Federal agencies.

**C131 State Agencies Concerned with Mining and Mineral Resources in Arizona, 2009.** Contains names, addresses, and pertinent people at state agencies concerned with mines and mineral resources.

**C132 County Agencies Concerned with Mining and Mineral Resources in Arizona, 2009.** Includes a listing of addresses, phone numbers, and websites.

**C133 Arizona Gem Shows - 2009-2010,** Includes date, location, sponsoring group, contact person.

**C134 Earth Science Clubs - 2009-2010,** Includes rockhound, lapidary, and prospecting organizations

## New Website Uploads

The Department has recently scanned and uploaded U.S. Bureau of Mines' *Information Circular 9216 In Situ Leach Mining—Proceedings* to our website. The 112-page IC was scanned in color and is available for viewing or as a free download. [Read Report](#). The report discusses the in-situ leaching of copper deposits and focuses on the Santa Cruz deposit.

*The Primary Copper Industry of Arizona* reports were published for years 1974-1992. Thirteen of these reports are currently scanned and available as pdfs on our website. Additional production data from 1949 - 1973 was published in the Statistical Summaries. For the time period post-1992, less detailed information was published in our annual mining summaries that includes copper production by mine. [See the Reports](#).

Many other reports remain in our library for examination. Do you have a particular need? ADMMR will process your scanning request for a nominal fee, which furthers our web posting efforts.

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### **Oatman Exploration Data Acquired**

The Department recently received a donation of files and maps from an early 1990s exploration project in the Oatman District of Mohave County. The exploration work was conducted largely in the northwestern portion of the district, covering the Black Wonder and Moss mines. The data includes geology and geochemical data, drill logs and assays, and metallurgical and reserve reports. The donation includes 24 linear inches of files and over 40 maps. The information is available for review in our office. The reports and most maps have been scanned and may be obtained on DVD for \$50, including shipping and handling.

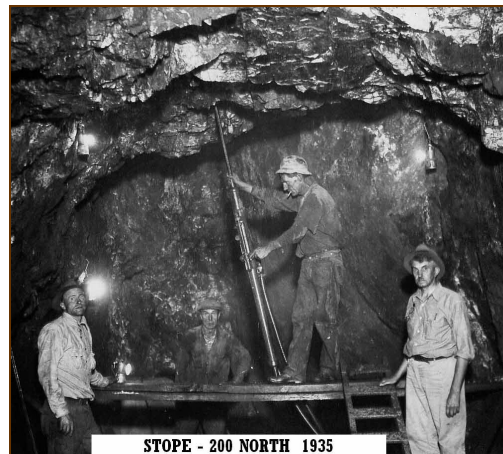
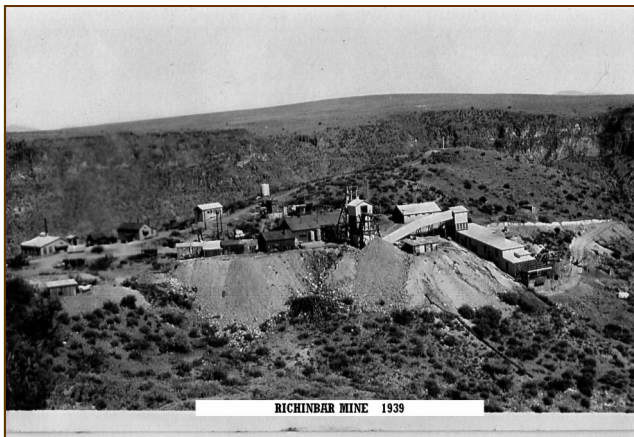
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## Richinbar Photo Collection Enriches Department Archives

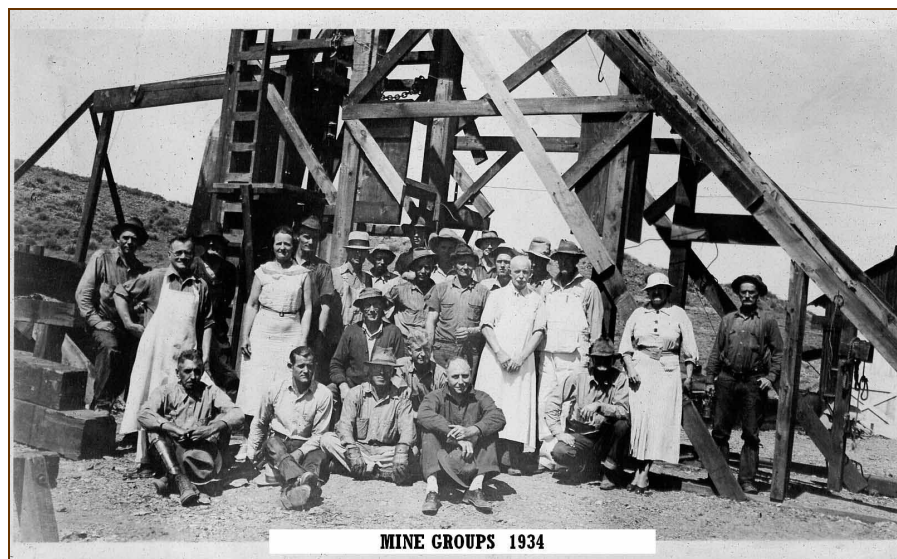
The Friends of the Agua Fria National Monument, in the Fall of 2008, donated 142 photographs of the Richinbar mine, Yavapai County, to the Department. The Department was provided with digital copies of the entire collection. The photographs date from the early 1930s and chronicle the development of the mine during that period and the lives of the people involved with the mine.

The photos were scanned in 2008 by Carlton Wheeler from an old album his family had when they left the Richinbar in 1939.



*A rare underground photograph from this time period.*

The Richinbar provided employment to scores of workers and produced over 4,500 oz. of gold in its glory days. The mine also produced copper, silver, and lead.



## Thank You Ray!

The Department announces the retirement of Dr. Raymond Grant from our Board of Directors. We wish to thank him for his many years of distinguished service. Ray was appointed to the Board in June of 2003 by Governor Janet Napolitano and served until January 2009.

Ray, an advanced mineral collector, geologist, and Museum supporter, was committed to uplifting and promoting the interests of the Department and Museum. He is a current and past chairman of the Arizona Mineral and Mining Museum Foundation, a Museum support organization that has been

essential and indispensable to the Museum for many years. Ray was also instrumental in establishing the Arizona Mineral Symposium, an annual event that provides a forum for both professionals and amateurs interested in mineralogy. The symposium promotes sharing of cumulative knowledge of mineral occurrences and provides stimulus for mineralogical studies and new mineral discoveries.

Ray was a professor of geology at Mesa Community College until his retirement in January of 2001. He received his M.S. and Ph.D. degrees in geology from Harvard University. Grant co-authored the comprehensive and authoritative *Mineralogy of Arizona*, third edition, as well as numerous other mineral and geological publications. Ray gave the rights to his publication, *Checklist of Arizona Minerals*, Second Edition, to the Department in 2007, where it was released as Open-File Report 07-25.

“Ray’s tenure of service included some tumultuous times for the Department and Ray was always there to support us,” states Director Dr. Madan M. Singh. “His guidance and wisdom served the agency well during some crucial periods. We greatly appreciate his efforts on our behalf and we will miss him.”



Dr. Raymond Grant